

## Article

# Exploring the Effects of Innovation Strategies and Size on Manufacturing Firms' Productivity and Environmental Impact

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**Abstract:** In economies that are based on natural resources, efforts to achieve sustainability still seem unclear, especially in manufacturing companies. As a result, from a business perspective, many manufacturers have adopted various strategies to maintain their competitiveness in line with environmental regulations. In addition to product and process innovation, we have analyzed innovation based on product–service innovation (PSI), or servitization, which is seen as key to promoting more resource-efficient economies. This study examines the effects of innovation strategies on productivity and environmental impact. Based on data extracted from the National Innovation Survey of the manufacturing industries of Peru, a sample of 791 companies were analyzed. Our findings indicate that, although only a few companies carry out product and process innovation and especially product–service innovation, when they do, they have a positive effect on both productivity and environmental impact. However, this relationship is affected by the size of the company. Thus, the innovation strategies have a greater positive effect on environmental impact in large companies than companies with fewer than 50 employees. Finally, despite the importance of product–service innovation, it seems that this strategy is not yet established in Peruvian manufacturing companies. Given the positive effect on productivity and environmental impact, we conclude by emphasizing the importance of establishing public policies aimed at disseminating and promoting this type of innovation, with specific support for companies with fewer than 50 employees.

**Keywords:** innovation strategies; productivity; environmental impact; manufacturing; size



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## 1. Introduction

In a broad sense, while sustainability has gained attention among organizations trying to combine economic, environmental, and social performance in their business strategy [1], its implementation has led to more involvement in complex global challenges, such as climate change or depletion of natural resources [2]. Traditionally, empirical evidence has shown that manufacturing companies consume many resources as a consequence of the traditional practices they follow in their production process [3]. However, it seems that industries in general are increasingly adopting strategies to be able to change this path and face the new challenges of society towards sustainability [4,5]. In this context, the role of manufacturing is key, not only because companies can achieve higher levels of productivity in the economy of a country, but they can promote major technological changes [6]. Recent studies highlight that manufacturers can change their production systems towards sustainability based on innovation [7–10]. Latterly, the focus has been on the paradigm shift towards the circular economy. This new framework establishes new principles for innovation towards regenerative production and consumption patterns, focusing on reducing the use of resources, extending the lifetime of products, their parts

and components, and eliminating waste and pollution [11]. In this sense, the manufacturing industry is called upon to innovate its products and processes, contributing to the realization of a circular economy and achieving economic benefits at the same time.

The literature on innovation has normally focused on product and process innovation and their effects on economic performance [12], considering diverse indicators such as productivity [13–15] and environmental sustainability [16,17], among others. Recently, there has been growing interest in understanding how servitization or product–service innovation (PSI) can also have positive effects on the performance of manufacturing companies and achieve competitive advantages [18,19]. Some recent studies analyze the relationship between product–service innovation and productivity, finding that companies that implement servitization practices significantly increase their operating margins [20], sales [21] and employment [22], among other indicators. Furthermore, within the field of environmental studies, servitization is presented as a useful strategy to advance resource efficiency and reduce environmental impact [23,24]. That is, it appears to reduce environmental impact [11]. In this sense, innovation in business models through servitization is seen as an important strategy to contribute to a circular economy. However, servitization sometimes does not provide the expected benefits [25] and can increase operational and commercial risk [26].

Although many studies shed great light on the direct and individual effects of servitization within a company, very few still focus on the broader effects (e.g., environmental or social impacts). To address this gap, our article aims to empirically evaluate the effects of product–service innovation (and other traditional innovation strategies) on productivity and the environmental impact of the company, through a sample of 791 manufacturing companies in Peru. From a contextual perspective, the global added value of manufacturing has grown, strongly influenced by emerging and developing economies [27]. In this sense, this study focuses on Peruvian manufacturing to verify whether these companies also follow this path. In the last decade (2008–2018), the GDP of Peruvian manufacturing has experienced an annual growth rate of 2.3% and represented 13.3% of GDP in 2018. This trend has been accompanied by a large labor force (1.4 million workers in 2018), which constitutes an important source of employment [28]. Furthermore, another important aspect to highlight is that, over the last decade, progress towards a green industry has been on the public agenda. For example, with the National Productive Diversification Plan [29], strategies for the future of the industry were presented. Thus, a series of initiatives have been developed, such as the “Sustainable Public Procurement and Eco-labelling Project Aimed at SMEs” [30]. Similarly, to help preserve the environment, the Ministry of Production of Peru has been approving environmental impact studies, with the majority (91.8%) being manufacturing companies [28]. Despite all these initiatives for greener industry, the studies on PSI or servitization in Peru are still non-existent. The few studies that exist focus on the environmental impact of the extractive or mining industries [31].

Our original research design follows recent trends in servitization research [32], exploiting the information provided by the National Innovation Survey in the Manufacturing Industry of Peru to determine which manufacturing companies also offer services, with econometric regressions used on a sample of manufacturing companies that achieved product, process, and product–service innovations. The results show that all innovation strategies have positive effects on the productivity and environmental impact of manufacturing firms and that large companies have greater significant effects on the relationship between innovation strategies and productivity/environmental impact than small companies. This is particularly observed in large companies with product–service innovation, even though an exceedingly small proportion of companies carry out this innovation strategy.

The paper is structured as follows: Section 2 introduces the literature review and the development of some hypotheses; Section 3 details the databases and tests the hypotheses; the empirical results are discussed in the Section 4; lastly, Section 5 provides some brief conclusions, limitations, and suggestions for future avenues of research.

## 2. Literature Review and Hypothesis Development

### 2.1. Sustainability, Productivity and Environmental Impact in Manufacturing Firms

Manufacturing industries play a pivotal role in the national economies of countries all around the world [33]. However, empirical evidence shows that the industrial sector consumes a huge quantity of natural resources and exerts considerable pressure on the environment due to the levels of pollution inherent to the production process [3]. During the last two decades, numerous studies have been developed to shed light on how manufacturing industries could transform their production systems in line with the aspirational targets of the Paris Agreement and sustainable development goals [5]. In this context, sustainability has become an imperative responsibility for the manufacturing industry to survive in contemporary society. This is due to the lack of a sustainability focus in traditional manufacturing practices [4] and the great pressure to reduce the overall manufacturing costs in order to sustain its position in hypercompetitive domestic and global markets [34]. Usually, an environmental assessment of manufacturing systems includes: fuel consumption, exhaust emissions and noise, air and water pollution, recycled materials after the manufacturing of non-reusable parts (including solid wastes such as metal products and paper products) and producing carbon emissions in manufacturing [35]. These practices could impact the organization or the business model in, for example, efficiency, productivity, profits, increased exports, etc. [36]. In addition, innovations might have a greater impact on the development of more sustainable production cycles, new products and services [37]. In this sense, innovation strategies should generate positive economic, social, and environmental results at the same time. However, those outcomes are not easy to establish given the uncertainties of the innovations [38]. In any case, although researchers have broadly discussed issues related to sustainability-oriented innovation, there is a lack of consensus on the empirical evidence for these relationships [36].

Many studies highlight the importance of innovation for sustainability. In particular, there are studies that address the transformation from innovation to sustainability [8]; service innovation in sustainable product–service systems [9,10]; green servitization for sustainable supply chain operation [39]; innovation in the circular and performance economy [40], among other topics. In recent decades, there has been a growing interest in eco-innovation as a type of innovation that allows for both economic and environmental benefits [41–44]. Thus, for companies that eco-innovate, it would be possible to achieve a win–win situation in terms of competitiveness and sustainability. An eco-innovation is simply defined as “an innovation that improves environmental performance”, although “economic and social impacts play a crucial role in its development and application, and hence determine its diffusion path and contribution to competitiveness and overall sustainability” [42]. An eco-innovation may happen at different levels through products, processes, marketing methods, organizations and institutions, and thus produce anything from incremental to disruptive and radical impacts [45].

### 2.2. Manufacturing Innovation Strategies

Traditionally, manufacturing innovation strategies are related to technological (product and process) and non-technological (organizational and marketing) aspects that can affect the performance of an organization [46]. However, technological innovations are the most common in manufacturing industries. Thus, product innovations are considered improvements, as is the introduction of a new product or service to meet the needs of external markets. In other words, product innovation is the introduction of a good or service that is new or significantly improved with respect to its technical specifications, functional characteristics, product attributes, design, materials, components, embedded software, etc. It can also consist of improving the reliability of the product to meet customer requirements or market needs. Therefore, the objective of product innovation is to improve the quality and the brand of the company from the differentiation and positioning of its products in the market. It is important to highlight that product innovation can be accompanied by process innovations, new organizational forms, and marketing [47]. Process

innovations are, on the other hand, considered as new or improved processes; from the implementation of new machinery to the incorporation of quality systems, among other activities, with the aim to reduce unit production and distribution costs and to diversify the company's product offering. Therefore, process innovation can facilitate greater flexibility in production and product quality, as well as improve working conditions for employees and meet environmental requirements. On the other hand, process innovations, in addition to focusing on production or distribution processes, also focuses on support processes (purchasing, accounting, maintenance) using computer programs (such as ERP or SAP) that articulate different areas of the organization improving their effectiveness and productivity. Therefore, significant changes in techniques, equipment, management software are considered, which could be linked to organizational innovation [47].

There is ample evidence that both product and process innovation influence firm productivity, also in the Latin American context [14]. Productivity gains are related to production efficiency and factor savings. Some studies indicate that product innovation has a positive effect on revenues, somewhat less evident in process innovation [15]. The literature on product and process innovation has normally focused on the effects these outcomes have on the economic performance of the organization [12], such as productivity [13–15] or even how to achieve its sustainable competitive advantage. Under this idea, many organizations have not considered environmental and social factors [7]. In fact, some research highlights the disadvantages of innovation [48]. However, more and more, the literature on product and process innovation begins to show evidence that organizations are beginning to become aware of environmental sustainability [16]. Recent studies highlight that the development of digital technologies and the emergence of sustainable smart products has attracted great attention from industries and ecosystems [49]. Based on this discussion, we make the following hypotheses:

**Hypothesis 1a (H1a).** *Manufacturing firms that implement product innovations have a positive effect on the productivity of the firm.*

**Hypothesis 1b (H1b).** *Manufacturing firms that implement product innovations have a positive effect on the environmental impact of the firm.*

**Hypothesis 2a (H2a).** *Manufacturing firms that implement process innovations have a positive effect on the productivity of the firm.*

**Hypothesis 2b (H2b).** *Manufacturing firms that implement process innovations have a positive effect on the environmental impact of the firm.*

Despite the traditional classification, one of the most recent innovations among manufacturing industries is the addition of value by incorporating services to their core corporate offerings [50]. This phenomenon is also known as servitization, or product–service innovation (PSI). In fact, manufacturing firms are progressively innovating in services to escape the commodity trap and gain competitive advantage [18]. Thus, we consider it convenient to analyze this strategy independently. The marketing and management literature highlights the potential of servitization as a strategy to improve the competitiveness of companies [20]. The motivations that guide manufacturing companies to shift to the provision of product–services are: the need to halt the reduction of profits and to escape the lack of a differentiation trap [50]. From this point of view, servitization is a viable way to improve the economic performance of companies through different mechanisms. It is stated that servitization allows companies to set barriers to competitors and others, to lock-in customers, to differentiate the market offers and to diffuse innovations, as well as to get relevant information from the customers that is needed for further innovation. Additionally, other reasons that favor the offering of services are: the greater financial margin and stability of gains along the economic cycle, the trend towards outsourcing in

the market due to the need for flexibility and to the technological complexities that other organizations face, as well as the differentiation value of services [50].

On the other hand, the shift to PSI requires manufacturing companies to address organizational and managerial challenges [22], while different conditions may favour or hinder it [51–53]. Moreover, the shift to servitization sometimes does not provide the expected benefits. Neely [25] highlights important challenges for companies and the “servitization paradox”—when servitized companies generate lower profits as a percentage of revenues compared with purely manufacturing companies [26]. Other authors point out that the diffusion depends on the stage of maturity of the industry, the life cycle of the product [54], broader changes in the socio-technical context, or customer behavior, etc. Thus, services may serve to create economic and social value. More recently, it has been argued that the sustainability challenge will be a key driver of future developments in service activities [55,56]: first, new services may be created based on a new economic model, supporting primary and manufacturing activities that are organized in the local economy and the new needs appearing in that context; second, services may be innovative and have fewer impacts on the environment by themselves. From this viewpoint, the servitization strategy may support companies in achieving environmental objectives, which are beneficial for them and for their customers, and eventually for society. Within the field of environmental studies, servitization is presented as a useful strategy to make progress in resource efficiency and diminishing the environmental impact of economic activities [23,24]. A product–service system should be defined as “a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfying to customer needs and having a lower environmental impact than traditional business models” [24].

In recent literature on the circular economy and resource efficiency, great emphasis is placed on the innovation of business models towards the provision of services or products as a service [57–60]. According to the literature, the business models based on selling goods as services or performance are the most profitable and resource-efficient in the circular economy. Through its focus on system solutions, they internalize risk and waste costs. Moreover, the retention of ownership of goods and embedded resources creates corporate and national security of resources. Therefore, the design of eco-efficient product–service systems sets the basis for re-thinking servitization as an innovation that goes further than economic gains for the companies and provides societal benefits. Some specific case studies have been carried out which show how different servitization examples contribute to improving environmental performance through several indicators [58] and has been constructed in different ways [61]. Neely [25] employs a rank of service activities to distinguish between servitized and purely manufacturing firms. In previous studies on the impact of servitization, measures to evaluate economic performance included the indicator ‘EBIT margin’ and ‘Tobin’s q’ to assess the effectiveness of the service business model innovation employed [62], among others. The indicators for measuring the environmental impact of the service strategy are also varied. Life Cycle Assessment (LCA) is one of the usual methods used to compare product–service systems with equivalent single products [63]; other indicators include corporate environmental footprint [64,65]. Despite existing evidence, services in general, and servitization in particular, are not inherently more environmentally friendly than conventional product-based business models [66]. This points out the need for purposely innovating towards environmental servitization. Investment in servitization produces a variety of effects. In other words, there is no agreement that the effects of servitization are always positive from an environmental or sustainability perspective [20,57,61]. This directs our study to a novel approach that focuses on data on innovation. Based on this evidence, we make the following hypotheses:

**Hypothesis 3a (H3a).** *Manufacturing firms that implement product–service innovations have a positive effect on the productivity of the firm.*

**Hypothesis 3b (H3b).** *Manufacturing firms that implement product–service innovations have a positive effect on the environmental impact of the firm.*



### 2.3. Firm Size, Innovation, Productivity and Environmental Impact

The review of the empirical literature on the relationship between innovation, productivity, environmental impact, and company size is not immune to divergences that bring about debates that ultimately advance the understanding of this study phenomenon. Firstly, in the literature on innovation, traditionally the Schumpeterian approach has “dominated”, since it is based on the hypothesis that innovations are fundamentally promoted by large companies. On this basis, subsequent studies reinforce this idea and suggest that large companies invest more in R&D [67] and, therefore, are more likely to have a greater absorption capacity than SMEs [68]. In this way, large companies have greater opportunities to capitalize on their resources and capabilities [69] and thus develop new products [70]. This advantage is usually prolonged due to multiple factors, such as better access to external capital and hiring highly qualified personnel, etc. [67]. In contrast, other studies suggest that SMEs can be more innovative [71] because they are proactive in the search and use of external knowledge [72], they are more flexible in their structure and adapt to market demands [73] and are effective in co-ordinating their resources in the development of new products [74].

Secondly, in the sustainability literature, it can be general stated that all companies can generate impacts throughout the entire life cycle of a product. However, SMEs play an important role in this context since they represent most existing companies [75], face a series of difficulties in integrating sustainability into their core business processes and remain largely reactive to environmental issues [34]. Moreover, research on firm size and eco-innovation also points to the importance of being a large company in order to take on environmental objectives of innovation [44]. Przychodzen and Przychodzen [76] suggest that larger companies exhibit more eco-innovative behavior due to having more free cash resources and having less exposure to financial risk. Arranz et al. [77] reach a similar conclusion when they find that large companies have a greater predisposition for the adoption of environmental objectives. However, some evidence in emerging countries has shown that innovative manufacturing SMEs present performance benefits from eco-innovation [78]. Therefore, based on all the reviewed literature, we propose the following hypotheses:

**Hypothesis 4a (H4a).** *Firm size has a positive effect on the relationship between manufacturing innovation strategies and the productivity of the firm.*

**Hypothesis 4b (H4b).** *Firm size has a positive effect on the relationship between manufacturing innovation strategies and the environmental impact of the firm.*

### 2.4. Innovation, Sustainability and Productivity in Developing Economies

Sustainable production and consumption are a major challenge for businesses around the world, especially for emerging and developing countries [79]. Beyond the policies that can influence how industries and companies develop innovations for a more sustainable production and consumption model, it is interesting to analyze the efforts put in place by companies themselves. In this sense, it has been suggested that sustainable production and consumption strategies can affect sales performance; therefore, our research on innovation strategies and their impacts on economic and environmental objectives of firms is of utmost interest.

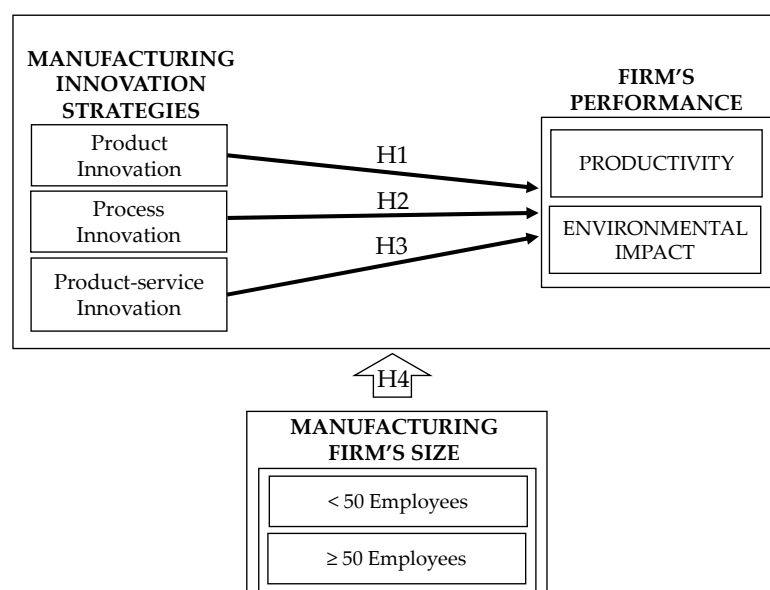
Among the studies that focus on the Latin American context, it has been shown that small and medium-sized enterprises have lower productivity levels than SMEs in developed economies. In fact, it has been shown that manufacturing SMEs with a strong export focus, especially those that manage to join global value chains, achieve productivity improvements. This relationship would be due to greater exposure to best practices and frontier technologies, compared to firms that remain focused on domestic markets [80]. Another study, which focused on analyzing the interaction between knowledge management competencies, firm internationalization and productivity in African countries, also found

significant differences between exporting and non-exporting firms (specifically, service and signaling competencies which are conditioned by firms' relationship with exporting). Therefore, exporting firms need to create a knowledge-intensive inter-firm network to improve their business models; this leads to higher productivity levels [81]. In contrast, the authors suggest that African firms focused on domestic markets need to improve their organizational absorptive capacity before turning to external technology and service providers. Without such absorptive capacity, the impact of external suppliers is likely to lower the productivity of non-exporting firms in this context.

In addition to the differential impact on the productivity of developing country firms according to their market orientation, it is relevant for the purpose of this article to analyze previous evidence on eco-innovation in developing countries. The literature on eco-innovation or environmentally positive innovation is abundant in the context of developed economies. However, it is not clear that the same factors and effects are equally applicable to firms in emerging markets and low-income countries [82]. Recent studies have found that the main barriers to eco-innovation are related to uncertain market demand, high investment costs, lack of knowledge and financial resources, poor co-operation between firms, government agencies and academia, and lack of skilled personnel and R&D investment [82,83]. Meanwhile, in low-income countries, subsidies, R&D spending, access to formal sources of knowledge, co-operation with external agents, and spending on staff training are critical factors in driving eco-innovation [84].

The achievement of environmental objectives through innovation varies greatly depending on the characteristics of firms in developing countries themselves. For example, in a study for Brazil [83], it is shown that multinational companies in advanced sectors, such as electronics, information technologies and automotive industries, develop their product innovations in research centers abroad while maintaining little co-operation with local authorities. On the other hand, micro and small enterprises are based on extractive processes and have little management capacity to develop innovations, as well as difficult access to finance.

In any case, the determinants and preconditions to innovation are remarkably different among Latin American countries [85]. Some authors state that this region serves as a "natural laboratory" for testing existing theories originating from the USA and Europe [86] and argue that Latin America is an under-researched region that has the potential to yield new and important insights into the innovation and internationalization of firms [87]. Thus, this literature review justifies the present study as we address a complementary perspective on innovation strategies and the effects on productivity and environmental performance of firms in developing countries. In contrast to the previous literature, the aim is to analyze specifically innovative firms and to determine which of the innovation strategies result in better economic and environmental performance. Figure 1 presents the hypotheses formulated in a theoretical model.



**Figure 1.** Theoretical model.

### 3. Method

#### 3.1. Data Description

The data were obtained from the National Innovation Survey in the Manufacturing Industries of Peru (ENIIM). The ENIIM data are collected by the Peruvian Institute of Statistics and Informatics every three years. The ENIIM uses stratified random sampling by localization, firm size, and industry. The final sample of this survey consisted of 1541 manufacturing firms distributed in small companies (29.7%), medium-sized companies (5.5%) and large companies (64.8%). The sample was obtained from the total population of 188,650 firms in Peru [75]. Our study uses information available from the third survey and covers the period from 2015 to 2017. For its part, the information was collected through direct face-to-face surveys, which involved the participation of an officially qualified pollster and informants who were the firm's managers or owners. In accordance with our research objectives (to know whether innovation strategies affect the productivity and environmental impact of manufacturing firms), we focused on Chapter VII of the ENIIM that deals with innovation outcomes (a detailed version of the survey and questionnaire is available by this link <http://inei.inei.gob.pe/microdatos/> (accessed on 20 July 2020)). Thus, the study focused only on companies that are engaged in product, process, and service innovation. For instance, the survey includes the following questions: (1) "During the 2015–2017 period, in relation to product innovations, did the company manage to introduce a new or significantly improved product to the market?"; (2) "During the 2015–2017 period, in relation to process innovations, did the company manage to introduce a new or significantly improved process into the company?"; (3) "During the 2015–2017 period, in relation to service innovations, did the company manage to introduce a new or significantly improved service to the market?". As such, we take product innovators to be those companies that responded positively to the introduction of product innovations, but negatively to service and process innovations. Likewise, we consider process innovators to be those companies that responded positively to the introduction of process innovations, but negatively to product and service innovations. Lastly, we take product–service innovators to be those companies that responded positively to the introduction of both product and service innovations together. Using these criteria, we included 791 companies in our total sample (Table 1), 266 being <50 employees and 525 ≥ 50 employees.



**Table 1.** Sample composition by industry and size (in absolute and in percentage).

Industry	Absolute		Percentage	
	<50 Employees	≥50 Employees	<50 Employees	≥50 Employees
Food products processing	30	105	11.28%	20.00%
Beverage manufacturing	5	10	1.88%	1.90%
Manufacture of textile products	12	38	4.51%	7.24%
Garment manufacturing	20	26	7.52%	4.95%
Manufacture of leather products and related products	14	13	5.26%	2.48%
Wood production and manufacture of wood and cork products	13	11	4.89%	2.10%
Manufacture of paper and related products	7	16	2.63%	3.05%
Printing and playback of recordings	14	15	5.26%	2.86%
Manufacture of coke and petroleum refining products	3	5	1.13%	0.95%
Manufacture of chemical substances and products	18	49	6.77%	9.33%
Manufacture of pharmaceutical products, medicinal chemicals	8	16	3.01%	3.05%
Manufacture of rubber and plastic products	19	50	7.14%	9.52%
Manufacture of other non-metallic mineral products	7	29	2.63%	5.52%
Manufacture of common metals	7	10	2.63%	1.90%
Manufacture of fabricated metal products, except machinery	18	54	6.77%	10.29%
Manufacture of computer products, electronics, and optics	4	2	1.50%	0.38%
Electrical equipment manufacturing	7	17	2.63%	3.24%
Manufacture of machinery and equipment n.c.p.	14	16	5.26%	3.05%
Manufacture of motor vehicles, trailers, and semi-trailers	8	9	3.01%	1.71%
Manufacture of other transport equipment	3	5	1.13%	0.95%
Furniture manufacturing	17	7	6.39%	1.33%
Other manufacturing industries	9	13	3.38%	2.48%
Repair and installation of machinery and equipment	9	9	3.38%	1.71%
<b>Total</b>	<b>266</b>	<b>525</b>	<b>100%</b>	<b>100%</b>

Source: Own elaboration from ENIIM Database (2018).

### 3.2. Variables

Based on the comprehensive questionnaires, two groups of variables could be observed. The first set of variables deals with firms' performance indicators such as productivity and environmental impact, while the second groups of variables deal with manufacturing innovation strategies. Thus, some of the main descriptions and a correlation matrix are shown in Table 2. Given the nature of the variables, the Spearman method was applied to calculate the correlations.

**Table 2.** Descriptive statistics and correlation matrix for the variables of interest.

Variable	Mean	SD	Min	Max	(1)	(2)	(3)	(4)	(5)
Productivity (1)	1.64	1.14	0	3	1				
Environmental Impact (2)	1.46	1.20	0	3	0.47 *	1			
Product Innovation (3)	0.31	0.46	0	1	0.15 *	0.10 *	1		
Product–Service Innovation (PSI) (4)	0.40	0.56	0	2	0.04	0.14 *	0.05	1	
Process Innovation (5)	0.61	0.49	0	1	0.29 *	0.23 *	0.02	0.05	1
Size	322.74	921.46	1	14447	0.07 *	0.12 ***	0.08 **	0.08 *	0.07 *

Total number of valid observations for all variables is 352. (\*) denotes statistical significance at 5% ( $p$ -value < 0.05), \*\*  $p$  < 0.01, \*\*\*  $p$  < 0.001.

To make a profile of the firm in our sample, we grouped companies together according to their innovation strategies, namely: product, process, and product–service innovation (PSI). This was fundamentally because innovation strategies are considered especially important in shaping the innovation portfolio of modern manufacturing companies [19]. In addition, we considered two size categories depending on the number of employees in the firm. The first group was made up of those manufacturers that have less than 50 employees and the second group consisted of those manufacturers that have more than 50 employees. Despite this, there were difficulties which arose around how to define the key variables of our study, productivity and environmental impact, which have the role of dependent variables in our study. The paper analyzes how the innovation portfolio contributes to achieving economic and environmental objectives based on the perceptions

of innovative firms. Therefore, the paper does not analyze the relation between innovation and actual productivity but the perception of firms on the perceived benefits of innovation, in terms of productivity and environmental positive effects. This perspective is different and useful to show how outcomes of innovation met innovative firms' expectations. Thus, we measured these variables through the items included in the questionnaire. These items measure the perceptions of managers on the impact of innovations carried out by their companies on their productivity and environmental impact. This way of measuring has been used by previous studies on environmental issues [88] and firms' performance [89]. Specifically, the question: "From the innovation that your company has obtained during the 2015–2017 period, what was the degree of importance on productivity of labour and of capital?" helped us to measure the productivity of the company, while the question "From the innovation that your company has obtained during the 2015–2017 period, what was the degree of importance on the environmental impact?" measured the positive environmental impact. Both questions are measured on a Likert-type scale of 0–3, where 0 indicates "none", 1 "low", 2 "medium" and 3 "high".

Figure 2 shows a bar graph with the proportion of responses provided by companies on the above questions. Additionally, the results are broken down by company size. This type of graph has been used in numerous previous studies, such as Vendrell-Herrero et al. [90], and it is useful to compare the results by groups of companies. We find that most companies present improvements in productivity (74%) and environmental impact (66%), respectively. The medium and high ratings were provided by more than half of the companies, specifically, 63% for productivity and 54% for environmental impact. This fact could indicate that companies perceive that the innovations obtained have positive effects on both productivity and environmental impact. Then, comparing the proportion of responses from both questions, it is observed that, in general terms, the companies affirm that innovation had a greater importance in their increase in productivity. In addition, we see a higher proportion of companies with more than 50 employees answering "high" for both questions compared to their counterparts with fewer than 50 employees, while for the rest of the answers the proportions are similar or slightly lower in large companies.

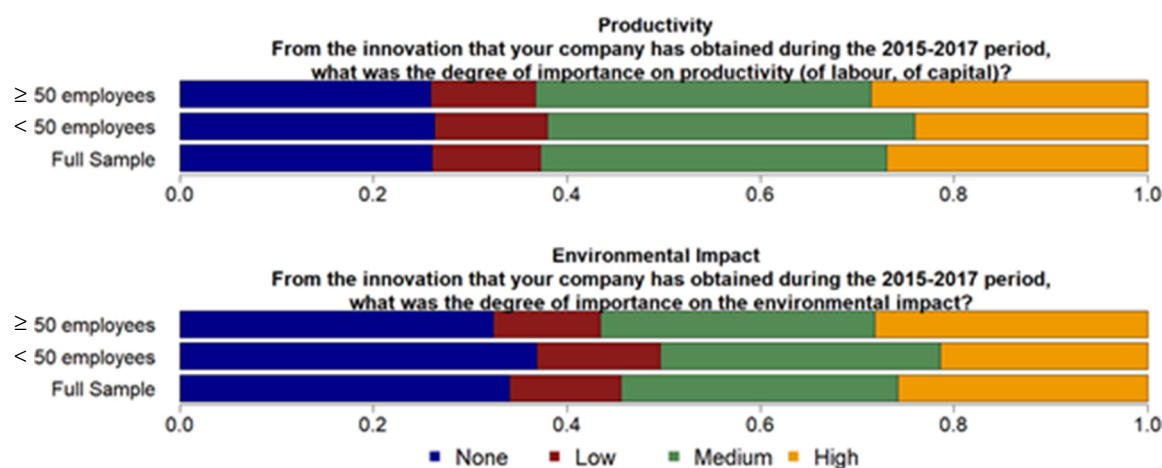


Figure 2. Productivity and environmental impact by firm size.

We considered three independent variables related to the manufacturing innovation strategies in the company. Thus, the Product Innovation variable represents whether the company mainly made new products, where 1 indicates that the company made a product innovation, and 0 otherwise. The second independent variable is Process Innovation, where the value 1 is assumed if the company implemented mainly an innovation with respect to the production process, and 0 otherwise. The third independent variable is the Product–Service Innovation that indicates whether the company innovated in both product and services combined—that is, "joint deployment". In this way, the variable can

present the value 0 if the company did not launch any product or service, 1 if the company launched one product or service and 2 if the company innovated one product and service together. This form to measure the servitization was made in previous studies [91]. We do not consider the level of maturity or complexity of the service because that information is not collected in the survey.

Table 3 shows a summary of the independent variables. Additionally, it breaks down the results by company size. In general, a slightly higher proportion of innovative large companies are observed compared to companies with less than 50 employees. Likewise, it is observed that the proportion of companies that innovate in processes is approximately double the proportion of companies that innovate in the product—approximately two thirds of the total. However, if we focus on the Product–Service Innovation variable, we observe that approximately 63% of all companies did not obtain innovation, either in the product or in the service innovation, and only a small proportion of companies, both in companies with more than 50 employees and with less than 50 employees, presented innovations in products and services together.

**Table 3.** Independent variables by size of the companies (in percentage).

Manufacturing Innovation Strategy	Full Sample	<50 Employees	≥50 Employees
Product Innovation	31.23%	28.20%	32.76%
Process Innovation	60.71%	57.14%	62.67%
Product–Service Innovation (PSI)			
None	63.09%	65.79%	61.71%
Product or service	33.38%	31.58%	34.29%
Product and service	3.53%	2.63%	4.00%

### 3.3. Method and Regression Models

In accordance with our research objectives, we estimated the effects of manufacturing innovation strategies on sustainability. We then focused on how each type of innovation affected the productivity and environmental impact using differentiated samples. The descriptive data and regression models were computed using R software. We applied a multivariate technique; specifically, we applied OPROBIT. Thus, the model took the following form:

$$Y_i = \beta_0 + \beta_1 ProductInnov_i + \beta_2 ProcessInnov_i + \beta_3 PSIInnov_i + \beta_4 PSIInnov_i + \vartheta_s + \varepsilon_i \quad (1)$$

where the sub-index  $i$  refers to the firms.  $ProductInnov_i$  is product innovation;  $ProcesInnov_i$  is process innovation;  $PSInnov_i$  is product or service innovation;  $PSInnov_i$  is product and service innovation; and  $\vartheta_s$  refers to the industry.  $\varepsilon_i$  is the error term. In this study, we try to evaluate the relationship between productivity (and environmental impact) and innovation variables according to firm size. Therefore, we fitted a total of 6 regression models.

## 4. Results and Discussion

The results show that innovation strategies have a positive effect on the sustainability of manufacturing companies according to the size of the company. Table 4 shows the result of the full OPROBIT analysis. In Columns 1–3, productivity is estimated according to the total sample and the size of the company. Similarly, in Columns 4–6 the environmental impact is estimated according to the total sample and the size of the company, respectively. It is important to notice that OPROBIT results are consistent with an OLS—that is, the results are qualitatively similar.

Table 4. OPROBIT analysis.

Variable	Productivity			Environmental Impact		
	Full Sample (1)	<50 Employees (2)	≥50 Employees (3)	Full Sample (4)	<50 Employees (6)	≥50 Employees (7)
Product innovation	0.5968 *** (0.1452)	0.8137 *** (0.2688)	0.4695 *** (0.1816)	0.3487 ** (0.1440)	0.0803 (0.2649)	0.3961 ** (0.1806)
Process innovation	1.1562 *** (0.1425)	1.0441 *** (0.2508)	1.2203 *** (0.1778)	0.8229 *** (0.1408)	0.4555 * (0.2498)	1.0278 *** (0.1775)
Product–Service innovation	0.1065 (0.1202)	−0.0807 (0.2276)	0.3246 ** (0.1517)	0.4116 *** (0.1187)	0.0962 (0.2285)	0.4995 *** (0.1495)
Industry FE	YES	YES	YES	YES	YES	YES
Pseudo R <sup>2</sup>	0.0516	0.0689	0.0602	0.0443	0.0497	0.0666
cut 1	−0.4212 **	−0.4397	−0.3466	−0.0884	−0.2900	−0.0548
cut 2	0.1655	0.1737	0.2409	0.4488 **	0.2944	0.4919 **
cut 3	1.8396 ***	2.0560 ***	1.8666 ***	1.7745 ***	1.7413 ***	1.8283 ***
$\chi^2$	108.01 (0.0000)	48.096 (0.0036)	83.119 (0.0000)	93.168 (0.0000)	34.918 (0.0896)	92.513 (0.0000)
Log Likelihood	−991.6109	−325.018	−649.4250	−1004.761	−333.601	−648.261
N	791	266	525	791	266	525

Coefficient (Standard error). Level signification: \*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$ . Probability of non-significance of the model ( $\chi^2$ ) between brackets.

First, in relative terms, if we analyzed the productivity and environmental impact variables (Columns 1 and 4), we can observe that these results are consistent with those studies related to eco-innovation [32,41–43,76]. In this sense, our results support the hypothesis that relates eco-innovation to the possibility of achieving a double advantage: environmental and economic. Thus, companies that, by carrying out their innovation strategies, manage to improve their environmental impact, together with an economic improvement, would be carrying out an eco-innovation [42]. Another relevant aspect to consider is that process innovation is significantly greater in comparison to other innovation strategies. Perhaps one explanation for this is found within the context of Peru; the main innovation outcome obtained by firms is the innovation process [92] through the acquisition of fixed assets [93]. The theoretical literature suggests that manufacturing firms seek to cope with this higher cost by introducing technological improvements, mainly in processes [94]. Porter [95] argues that innovation carried out to offset these costs would lead to improvements in the growth and competitiveness of firms. Thus, it can be stated that process innovation is linked to objectives such as cost savings and is one of the main triggers for eco-innovation [96]. Achieving greater efficiency in the use of materials and energy, using by-products, as well as reducing the generation of pollution, waste, and emissions, are some of the main impacts of eco-innovation, and may be realized through process innovation [82].

Second, if we analyze the productivity variable (Columns 1–3), we find results that may be interesting in this study. So, if we take into account the total sample and focus on Column 1, we can see that not all innovation strategies have positive effects on the productivity of manufacturing companies. Thus, only product innovation (coefficient = 0.5968 \*\*\*) and process innovation (coefficient = 1.1562 \*\*\*) have a positive effect. Therefore, it can be stated that these results support the hypotheses (H1a) and (H2a), respectively. In this way, these results coincide with the studies by [97] who found a positive relationship between product and process innovation with productivity in Latin American and Caribbean firms. However, no evidence was found to support product–service innovation having a positive impact on the productivity of Peruvian manufacturing companies. This result is not so strange since the evidence on servitization is still inconclusive [20]. In fact, some authors highlight the paradox that this implies for companies that incorporate services into their offer and do not manage to improve their economic results [52]. In this way, this result invites us to continue investigating to understand this phenomenon in the context of emerging countries and in Peru. However, if we carry out the analysis considering the size

of the company, we find some results that can help us better understand the relationship between innovation strategies and productivity. Thus, if we focus on companies that have less than 50 employees (Column 2), we find that not all innovation strategies have positive effects on the productivity of manufacturing companies—that is, only product innovation (coefficient = 0.8137 \*\*\*) and process innovation (coefficient = 1.0441 \*\*\*) have a positive effect, as shown in previous studies [71,74]. Therefore, it can be stated that these results partially support the hypotheses (H4a), since product–service innovation does not have a positive effect. Furthermore, if we focus on companies that have more than 50 employees (Column 3), we find that all innovation strategies have positive effects on the productivity of manufacturing companies—that is, product innovation (coefficient = 0.4695 \*\*\*), process innovation (coefficient = 1.2203 \*\*\*) and product–service innovation (coefficient = 0.3246 \*\*) have a positive effect. Therefore, it can be stated that these results support the hypotheses (H4a). In particular, we can affirm that product–service innovation has a positive effect on the productivity of large manufacturing companies, as found in previous studies [76,91].

Third, if we analyze the environmental impact variable (Columns 4–6), we find interesting results. Thus, if we take into account the total sample and focus on Column 4, we can see that all innovation strategies have positive effects on the environmental impact of manufacturing companies, namely, product innovation (coefficient = 0.3487 \*\*), process innovation (coefficient = 1.8229 \*\*\*) and product–service innovation (coefficient = 0.4116 \*\*\*). Therefore, it can be stated that these results support the hypotheses (H1b), (H2b) and (H3b), respectively. This means that innovation undertaken by Peruvian manufacturing firms may help to reduce the impact on the environment. In this way, these results coincide with the studies of De Madeiros et al. [16] and Yin et al. [49], who found a positive relationship between product and process innovation with the decrease in environmental impact and also with studies that focus specifically on eco-innovation types and environmental performance of firms [17], while they also coincide with other studies on the positive effect of servitization on environmental impact [32,58–60]. In this sense, it is important to highlight that adding services to the corporate offering implies a new focus on a product's life cycle and the provider's extended responsibility for all the life cycle stages of the product. Therefore, servitization may improve the environmental impact of the firm because it creates incentives to search for greater efficiency in the utilization of resources across the lifecycle, with a concomitant reduction in waste-related environmental impacts at any given level of economic activity. Despite the valuable findings mentioned, if we carry out the analysis considering the size of the company, we find some results that can help us better understand the relationship between innovation strategies and environmental impact. Thus, if we focus on companies that have less than 50 employees (Column 5), we find that only process innovation (coefficient = 0.4555 \*) has a positive effect on the environmental impact of manufacturing companies. Therefore, it can be stated that these results partially support the hypotheses (H4b), since product innovation and product–service innovation do not have a positive effect. In addition, if we focus on companies that have more than 50 employees (Column 6), we find that all innovation strategies have positive effects on the environmental impact of manufacturing companies—that is, product innovation (coefficient = 0.3961 \*\*), process innovation (coefficient = 1.0278 \*\*\*) and product–service innovation (coefficient = 0.4995 \*\*\*) have a positive effect. Therefore, it can be stated that these results support the hypotheses (H4b). More specifically, we can affirm that innovation strategies have a greater positive effect on environmental impact in large manufacturing companies, as found in previous studies [32,77].

Lastly, the McFadden's pseudo-R squared based on the likelihood ratio shows the significance of the regression models and we explored the existence of multicollinearity through the VIF, which were values lower than 5, being satisfactorily significant and which do not present multicollinearity problems [98]. For example, product innovation (VIF = 1.05), process innovation (VIF = 1.04), product–service innovation (VIF = 1.04) and industry (VIF = 1.12).



## 5. Conclusions, Implications and Limitations

### 5.1. Theoretical Implications

From a theoretical point of view, we assume that manufacturing innovation strategies can affect productivity [13–15] and environmental impact [16,17]. This research contributes empirically to showing that there is a positive relationship between the development of innovation strategies and the productivity and environmental impact in manufacturing companies. Based on a sample of 791 Peruvian manufacturing companies, we examined these relationships. We found that traditional innovation strategies, namely, product and process innovation, stand out the most in this relationship, with the process strategy being the one with the greatest statistical significance over the other strategies. This indicates that it is the most prevalent form of innovation in Peruvian manufacturing companies [93]. Hence, the process innovations allow for combining an economic and environmental gain, because they often imply cost savings linked to reduced environmental impacts, such as reduced use of materials and energy, as well as reduced waste management. However, the inclusion of new products with services has a greater positive effect on the environmental impact. Therefore, the servitization strategy also reinforces the achievement of environmental objectives.

If we make a more detailed analysis of these relationships considering the size of the company, our results suggest that there are differences. Thus, the firms with less than 50 employees focus their efforts on increasing productivity while companies with more than 50 employees divide their efforts between productivity and environmental impact. Possibly the “productive muscle” of large companies also makes it possible to focus efforts on caring for the environment, as has been mentioned by previous studies [76,91]. In any case, our empirical evidence shows us that even though very few companies carry out product–service innovation, they obtain greater positive effects on productivity and the environment, especially in large companies.

### 5.2. Practical Implications

Knowing how entrepreneurs perceive the impact of innovation on environmental and productivity goals is key to fostering their own innovation development. Likewise, highlighting this information, by disseminating it in the context of firms themselves, is of utmost importance to foster the spirit of innovation. In particular, the importance of process innovation, with positive impacts on productivity and the environment, points to the need to encourage process innovation. In this sense, stricter regulation in environmental terms is essential as compliance should indeed lead to the incorporation of technological changes that allow economic savings, improved productivity and a reduction in the desired environmental impact, all at the same time. The results of the study also confirm the positive impact of the servitization strategy on environmental performance. It is still a new strategy for companies and the incorporation of services implies the development or acquisition of new competences. Therefore, more policy effort should be put into fostering the acquisition of new skills among enterprises. Similarly, the creation of specialized service firms should be encouraged and linkages with other manufacturing firms should be fostered to contribute to the servitization strategy [99].

In any case, the results obtained are of interest for the innovative strategies of companies; however, they can differ depending on the firm size, which requires proper management of the innovation portfolio [19,100]. Beyond product and service innovation, the more recent strategy of servitization should be considered by companies. The incorporation of services into the core offering of manufacturing firms can contribute to improvements in their economic performance and to a better environmental performance of companies. As such, it can contribute to the transition towards the circular economy, as a new production and consumption paradigm that is more sustainable. Therefore, this type of innovation should be promoted by public policies. Perhaps environmental policies aimed at manufacturing should focus on giving incentives to small companies to apply improvements in their organizations and to help them implement more pro-environmental practices, just

as the Ministry of Production of Peru has been doing with the approval of environmental impact studies.

### 5.3. Limitations and Future Research

This study has limitations that should be highlighted. First, despite the ENIIM survey being used, the low number of key variable observations limits the analysis at the intra-industry level, allowing only interpretations of the industry as a whole. Second, due to the survey being cross-sectional in nature, it has allowed us to evaluate and analyze the effects of innovation on productivity and environmental impact, but our study does not assess innovation dynamics. We hope that future research can analyze these relationships in the long term through panel data. In addition, since our study of the data is focused on a single country, the results are far from generalizable to all manufacturing environments, and we recognize that more research is needed to test our hypotheses in other industrial contexts in emerging countries. Therefore, time and territorial dimensions (a greater number of countries) might influence the results and might provide important recommendations for policy. Third, further analysis could also focus on the existence of environmental regulations and the behavior of firms by sectoral branches in terms of innovation and the effects on their performance. Lastly, this study examines subjective performance measures; future investigations should include additional objective quantitative performance measures such as sales revenues, profits, expenditures, fuel consumption, exhaust emissions and noise, air and water pollution, recycled materials after the manufacturing of non-reusable parts, and producing carbon emissions in manufacturing. We hope that this study could be a starting point to encourage more research on this topic.

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